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A PRELIMINARY INVESTIGATION OF THE CHARACTERISTICS OF AIR SCOOPS ON A FUSELAGE

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NACA

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A PRELIMINARY INVESTIGATION OF THE CHARACTERISTICS OF AIR SCOOPS ON A FUSELAGE

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SUMMARY

An investigation of the characteristics of air scoops was made in the NACA propeller-research tunnel. The investigation showed that, at inlet-velocity ratios equal to or greater than 0.3, scoops in a forward position on the fuselage gave total pressures in the inlet nearly equal to free-stream total pressure. Scoops in positions for which the boundary layer is appreciable must, however, have some means of separating the boundary-layer air from the inlet air if satisfactory pressures are to be obtained. Critical Mach numbers of 0.55 are obtainable with scoops on the forward part of the fuselage.

INTRODUCTION

The present preliminary investigation of the characteristics of air scoops is one phase of an NACA research project to develop an efficient air inlet to meet the requirements of modern aircraft installations. The purpose of the investigation was to determine the effect of varying the inlet-velocity ratio on the pressures available in the duct inlet and on the indicated critical Mach number. The tests were limited to scoops tested in two positions on a streamline body. With the scoops in the midposition on the fuselage, several methods for separating the boundary-layer air from the inlet air were tried.

APPARATUS

The data of this report were obtained from tests made in the propeller-research tunnel on an NACA 111 fuselage shape with a fineness ratio of 5.0. The ordinates given in table I were obtained from reference 1 but are expressed in a slightly different form. The top of the fuselage was fitted with removable wooden covers to which scoops of various shapes were added. A rectangular stub wing of NACA 0015 section and 15-foot span was mounted in a midwing position on the fuselage. Figure 1 is a photograph showing scoop B-1-c mounted on the model ready for testing. The air was taken in by the scoop being tested, passed through an axial-flow fan, and exhausted through a duct leading to the wing tip. The air flow was increased or decreased by regulating the fan speed. Figure 2 shows the general arrangement of the model. The duct in the wing was in the form of a venturi tube, which was calibrated and used to measure the quantity of air flowing through the system.

Scoops were mounted in two different positions on the fuselage. (See fig. 2.) For the forward position, designated A, the entrance was $9\frac{1}{2}$ percent of the length of the fuselage back from the nose and for the midposition, designated B, the entrance was 37 percent from the nose.

The six scoops tested are shown in figures 3 to 8. The position of the scoop on the fuselage is indicated by the letter A or B in the designation. The shape of the scoop inlets, which was nearly rectangular with well-rounded corners, is shown by the numeral 1. Modifications in the shape of the lip and the afterbody as well as various means of boundary-layer control are designated by a final letter. Ordinates for the outer surface and the inner surface at the lip are given in tables II and III.

Scoops B-1-a, B-1-b, and B-1-c were similar except for various devices for separating the boundary-layer air from the inlet air. A screen having approximately the resistance of a radiator was fitted inside these three scoops more closely to simulate actual conditions. With scoop B-1-a, shown in figure 6, the boundary layer was bypassed under the screen and taken into the model along with the rest of the air. The inlet of scoop B-1-b, shown in figure 7, was entirely outside the boundary layer and provisions were made for the boundary-layer air to flow around the outside of the rest of the scoop. Scoop B-1-c, shown in figure 8, was similar to B-1-b except that, in order to prevent spillage of boundary-layer air into the duct, a sheet-metal shield was extended forward of the inlet a distance equal to the height of the inlet

METHOD OF TESTING

Tests were made of the model without a scoop to determine the pressure distribution over the fuselage and the boundary-layer thickness. The boundary-layer thickness was determined by surveys at several stations along the top of the model with rakes of total-pressure tubes.

Measurements of pressure distribution and pressure available in the scoop entrance were made at angles of attack of 0°, 8°, and −8° for inlet-velocity ratios varying from 0 to about 0.8. The 0° angle of attack was taken as representative of level flight with the scoop either on the top or on the bottom of the fuselage. The 8° angles of attack were taken as representative of a climbing attitude with the scoop either on the top or on the bottom of the fuselage. At these angles of attack, the lift coefficient is in the neighborhood of 0.4 with the low aspect ratio used. Pressures were measured along the top of the entrance lip on the center line of each scoop. The total pressure available inside the scoop was measured by a rake of total-pressure tubes located on the center line near the inlet.

RESULTS AND DISCUSSION

The following symbols are used in the presentation of the results:

p static pressure

q free-stream dynamic pressure

p/q pressure coefficient

V_i velocity in scoop inlet

V free-stream velocity

V_i/V inlet-velocity ratio

H total pressure available at entrance of scoop

M_{c} critical Mach number

h depth of scoop entrance, inches

x distance from top of scoop entrance, inches

α angle of attack of model, degrees

Two important factors affecting the flow into the duct inlets are the boundary-layer thickness and the surface-pressure distribution ahead of the point at which the inlet is to be placed. These characteristics for the test model are shown in figure 9.

The critical Mach number is plotted against inlet-velocity ratio in figure 10 for each of the scoops at 0° angle of attack. These critical Mach numbers were obtained from the maximum negative pressure coefficients p/q by the method of reference 2. As shown in figures 3 and 4, the afterbody of scoop A-1 was lengthened to make scoop A-1-a in an attempt to raise the critical Mach number, but the resultant increase was negligible. Scoop B-1-a was derived from scoop B-1 by lengthening the afterbody and changing the lip shape. (See figs. 5 and 6.) This change in shape resulted in an increase in critical Mach number of about 0.06. Most scoops showed a uniform increase of critical Mach number with increasing inlet-velocity ratio. The explanation of this effect is clearly given in reference 3.

The maximum speed over the lip of the scoop results from superposition of the induced velocities of the fuselage and of the scoop. If scoops of similar shape are placed in regions of different induced velocities on the fuselage, the scoop in the region of lowest induced velocity will have the highest critical Mach number. For this reason scoops in position A had higher critical Mach numbers than scoops in position B.

The variation of the total pressures in the scoop inlets with inlet-velocity ratio and angle of attack is shown in figure 11. The total pressure available, in terms of free-stream dynamic pressure, is plotted against the distance from the top of the duct expressed in terms of the total height of the duct. The total-pressure measurements were made on the center line of the duct entrance. The total height of scoop B-1-a included the boundary layer beneath the vane in the duct, which was set at 0.85 of the total height from the top of the duct.

It will be noted that, for the two scoops in the A position the pressures in the inlet are nearly equal to free-stream total pressure for inlet velocities at or above 0.3. At a given inlet-velocity ratio the pressures drop off for the 8° angle of attack; however, the conditions that cause the airplane to operate at an increased angle of attack also cause the inlet-velocity ratio to increase with a corresponding increase in total pressure.

The marked increase in pressure at inlet-velocity ratios at or above 0.3 in the modified B scoops in comparison with the original scoop B-1 is a result of separating the boundary-layer air from the inlet air. At the A position for which the boundary layer is thin, the effect of such a division would be less noticeable.

CONCLUSIONS

From tests of six air scoops in two positions (forward and middle) on a streamline fuselage, it was concluded that:

1. The scoops tested in the forward position gave total pressures in the inlet almost equal to free-stream total pressure for inlet-velocity ratios of 0.3 or greater.

2. When the scoops were in positions for which the boundary layer is appreciable, it was necessary to resort to some means of separating the boundary-layer air from the inlet air to avoid low total pressure in the inlet. Even with the methods tried, there was a decrease in the inlet pressures next to the body.

3. The critical Mach number increases with inlet-velocity ratio. For the forward position of the scoop, a critical Mach number of 0.550 was obtainable at an inlet-velocity ratio of 0.3. The highest critical Mach number for a scoop in the midposition was 0.525 at an inlet-velocity ratio of 0.3.

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2. von Kármán, Th.: Compressibility Effects in Aerodynamics. Jour. Aero. Sci., vol. 8, no. 9, July 1941, pp. 337-356.

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TABLE I

FUSELAGE ORDINATES

Distance from nose		Radius	
(in.)	(percent length)	(in.)	(percent length)
0	0	0	0
2.5	1.25	3.80	1.90
5.0	2.5	5.75	2.875
10.0	5.0	8.62	4.31
15.0	7.5	10.72	5.36
20.0	10.0	12.40	6.20
30.0	15.0	14.84	7.42
40.0	20.0	16.50	8.25
50.0	25.0	17.96	8.98
60.0	30.0	18.96	9.48
70.0	35.0	19.64	9.82
80.0	40.0	20.00	10.00
90.0	45.0	20.00	10.00
100.0	50.0	19.72	9.86
110.0	55.0	19.04	9.52
120.0	60.0	17.96	8.98
130.0	65.0	16.40	8.20
140.0	70.0	14.48	7.24
150.0	75.0	12.24	6.12
160.0	80.0	9.82	4.91
170.0	85.0	7.42	3.71
180.0	90.0	4.98	2.49
190.0	95.0	2.48	1.24
195.0	97.5	1.25	0.625
200.0	100.0	0	0

TABLE II

ORDINATES OF SCOOPS A-1 AND A-1-a

Station (in.) (1)	Scoop A-1		Scoop A-1-a	
	Inner ordinate (in.) (2)	Outer ordinate (in.) (2)	Inner ordinate (in.) (2)	Outer ordinate (in.) (2)
0.25	16.55	17.26	16.55	17.26
.50	16.50	17.51	16.50	17.51
.75	16.50	17.70	16.50	17.70
1.00	16.54	17.86	16.54	17.86
1.50	16.64	18.09	16.64	18.09
2.00	———	18.28	———	18.28
2.50	———	18.44	———	18.44
3.00	———	18.57	———	18.57
3.50	———	18.70	———	18.70
5.00	———	18.87	———	18.87
7.00	———	18.79	———	18.87
9.00	———	18.65	———	18.84
12.00	———	17.94	———	18.80
15.00	———	17.19	———	18.75
18.00	———	16.93	———	18.63
21.00	———	16.72	———	18.64
21.25	———	Tangent to body	———	———
31.00	———	———	———	18.51
35.375	———	———	———	Tangent to body
Nose radius	.31	———	.31	———
Ordinate to center of nose radius	16.85	———	16.85	———

[1]Stations are measured from nose of scoop.

[2]Ordinates are measured from center line of model.

TABLE III

ORDINATES FOR SCOOPS B-1 AND B-1-a

Station (in.) (1)	Scoop B-1 Inner ordinate (in.) (2)	Scoop B-1 Outer ordinate (in.) (2)	Scoop B-1-a Inner ordinate (in.) (2)	Scoop B-1-a Outer ordinate (in.) (2)
0.25	23.94	24.84	23.88	24.45
.50	23.88	25.07	23.83	24.63
.75	23.86	25.24	23.82	24.72
1.00	23.86	25.38	23.83	24.89
1.50	23.87	25.51	23.84	25.09
2.00	———	25.62	———	25.21
3.00	———	25.75	———	25.37
4.00	———	25.80	———	25.42
5.00	———	25.74	———	25.41
6.00	———	25.60	———	25.36
7.00	———	25.35	———	25.27
8.50	———	24.90	———	25.08
11.00	———	23.97	———	24.71
13.00	———	23.17	———	24.36
15.00	———	22.30	———	23.93
18.00	———	21.26	———	23.22
22.00	———	20.06	———	22.28
23.94	———	Tangent to body	———	———
25.00	———	———	———	21.59
28.00	———	———	———	20.92
31.00	———	———	———	20.29
34.00	———	———	———	19.72
36.00	———	———	———	19.36
39.00	———	———	———	18.84
41.61	———	———	———	Tangent to body
Nose radius	.375	———	.19	———
Ordinate to center of nose radius	24.30	———	24.14	———

[1]Stations are measured from nose of scoop.

[2]Ordinates are measured from center line of model.

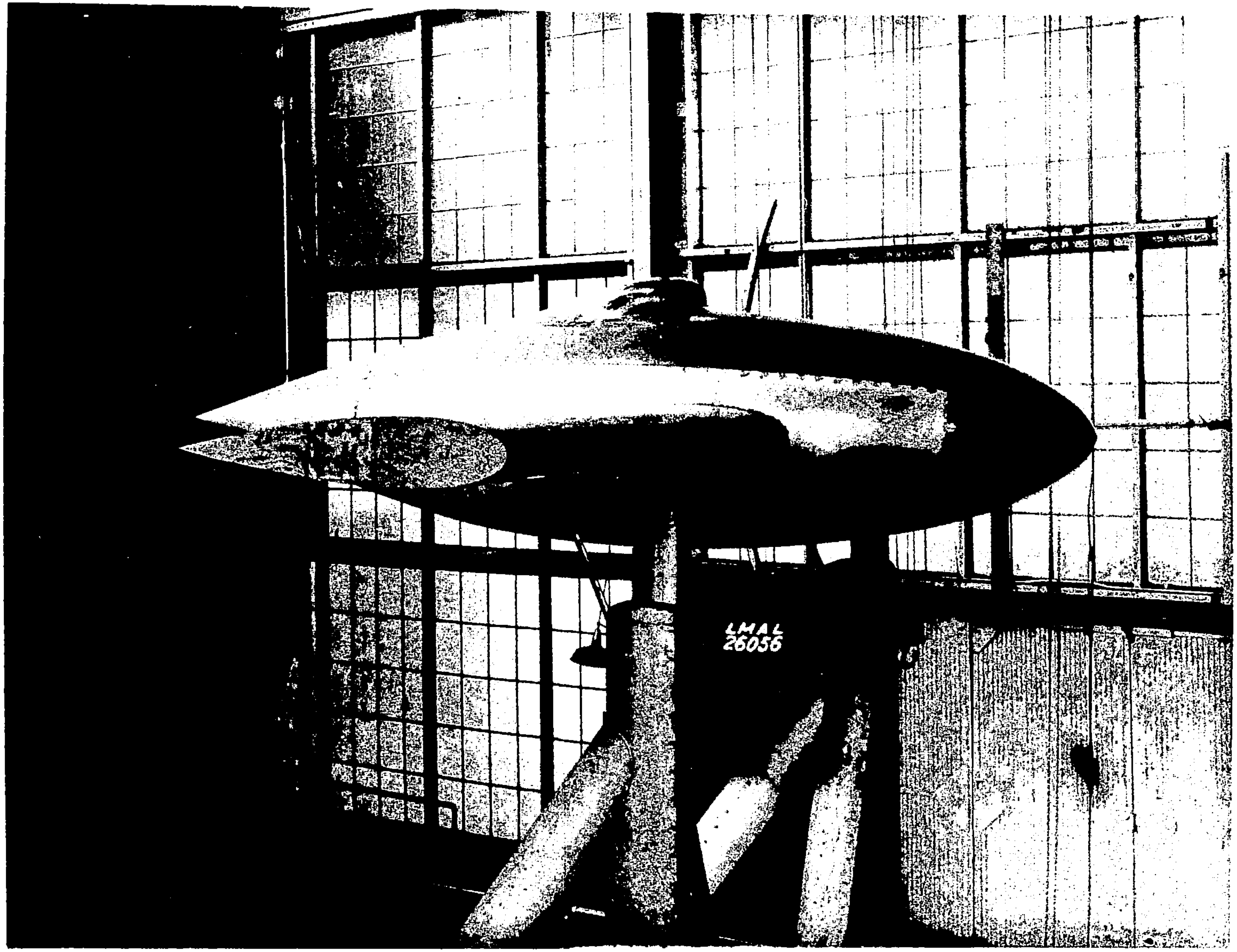

Figure 1.- Model with scoop B-1-c mounted in tunnel.

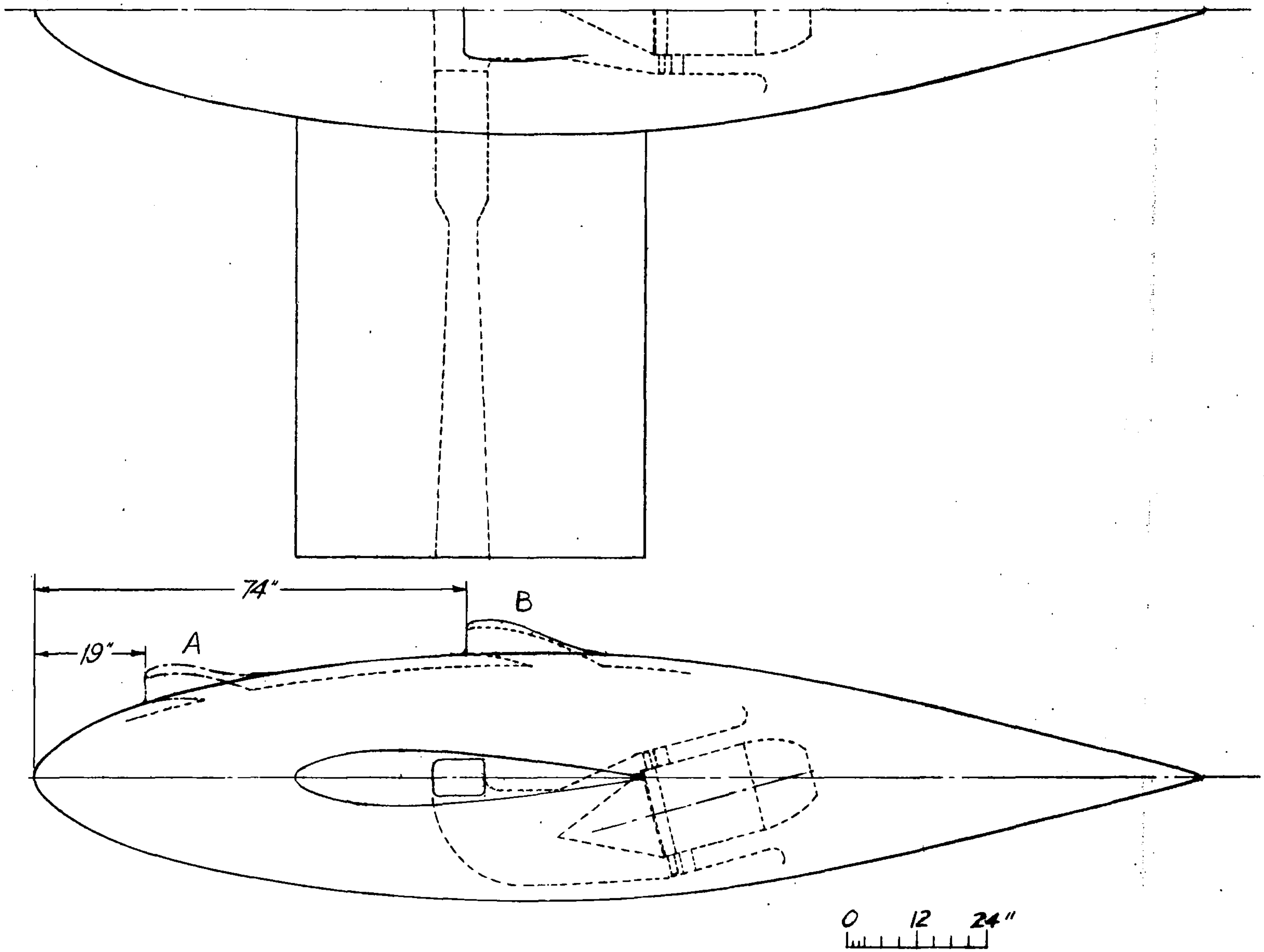

Figure 2.- General arrangement of model used in scoop investigation.

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Fig. 2

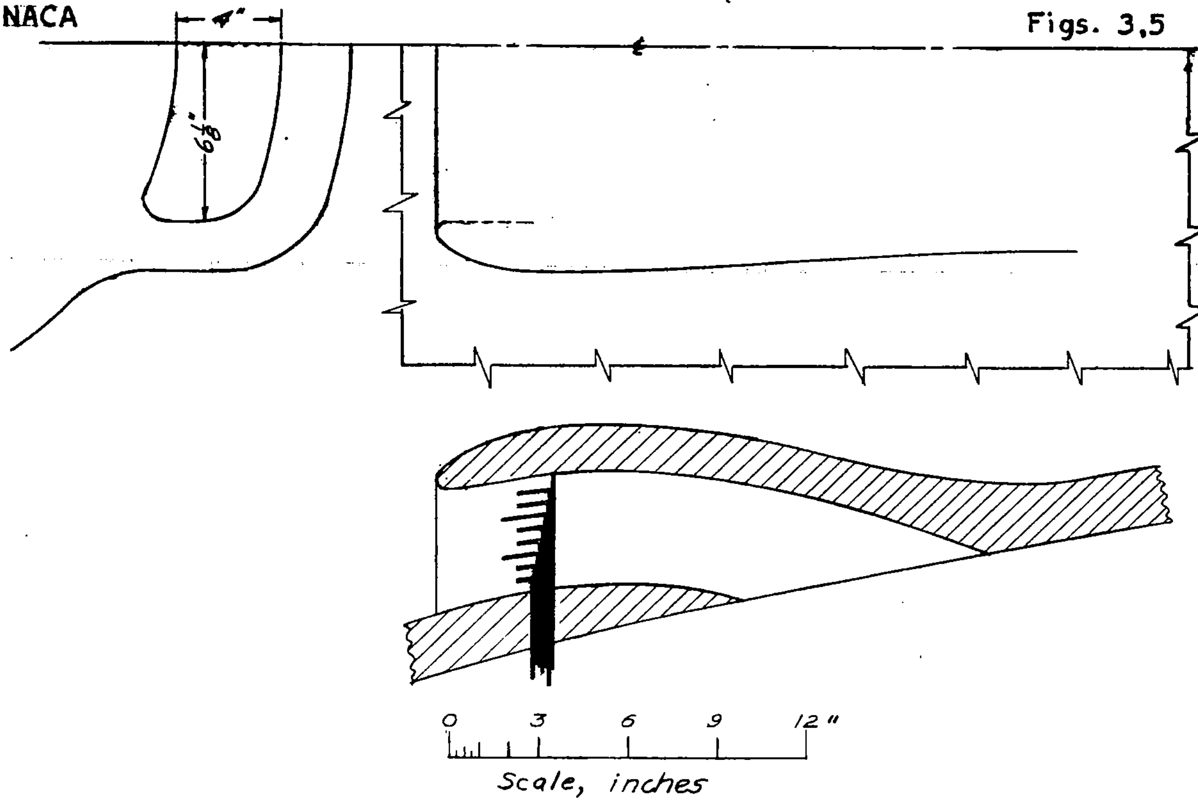

Figure 3.- Scoop A-1.

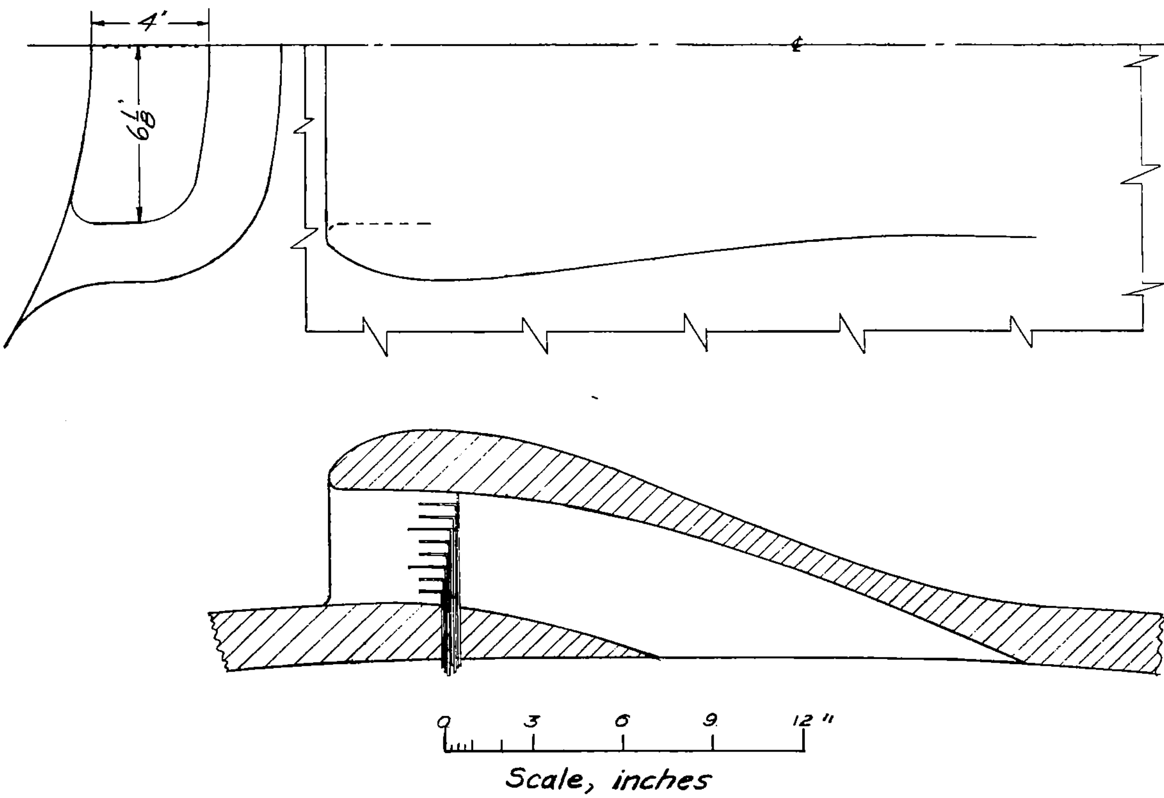

Figure 5.- Scoop B-1.

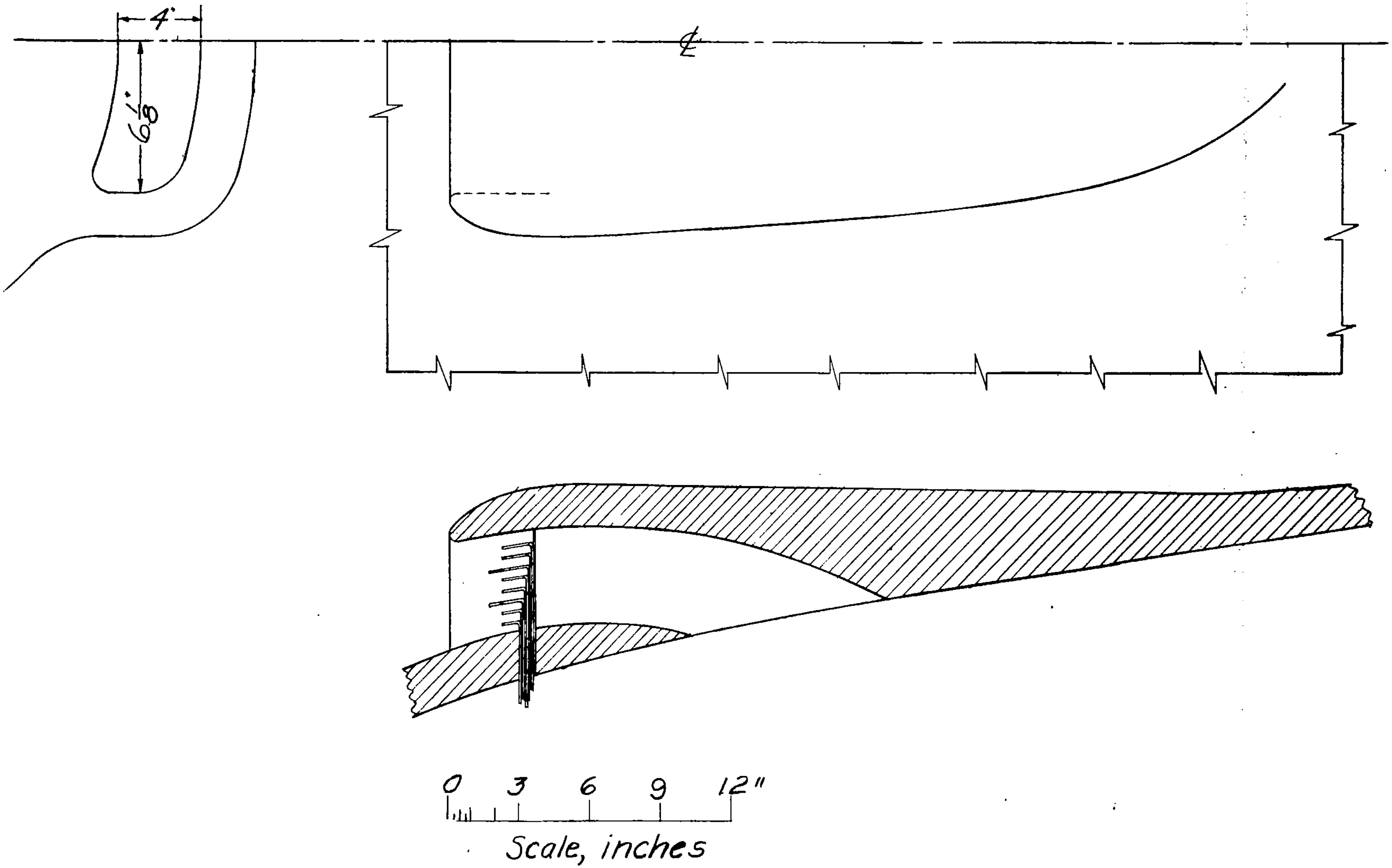

Fig. 4.- Scoop A-1-a.

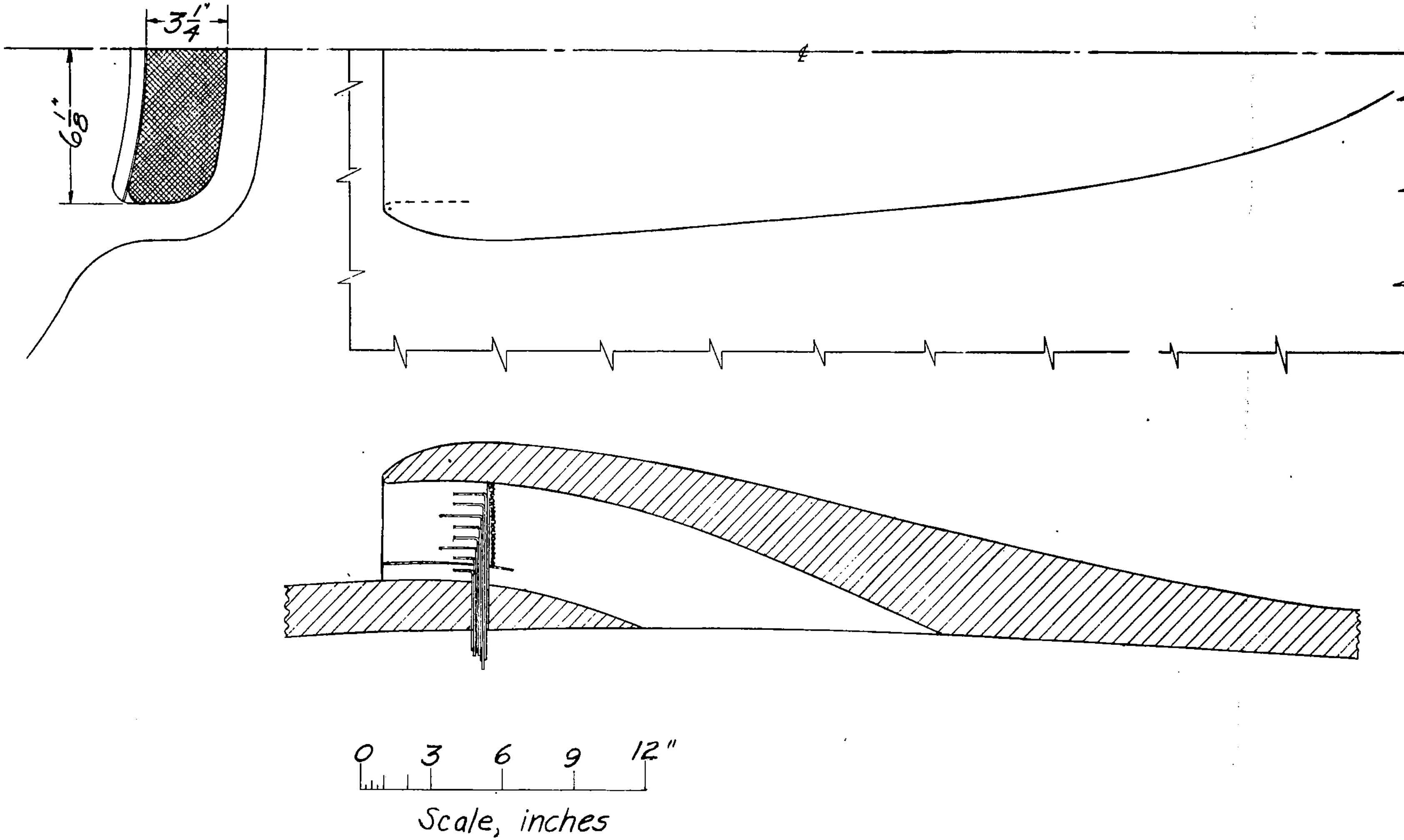

Fig. 6.- Scoop B-1-a.

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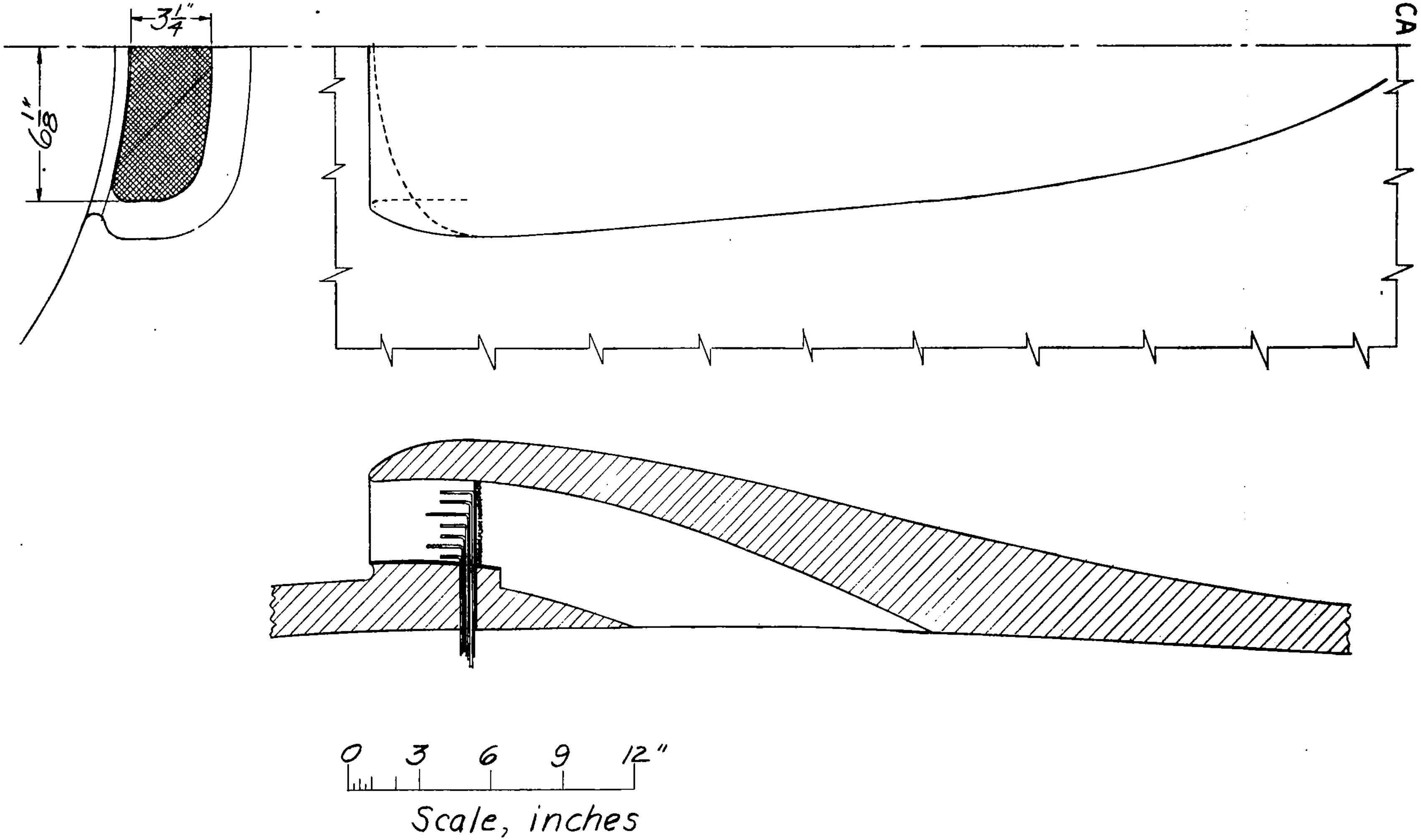

Fig. 7.- Scoop B-1-b.

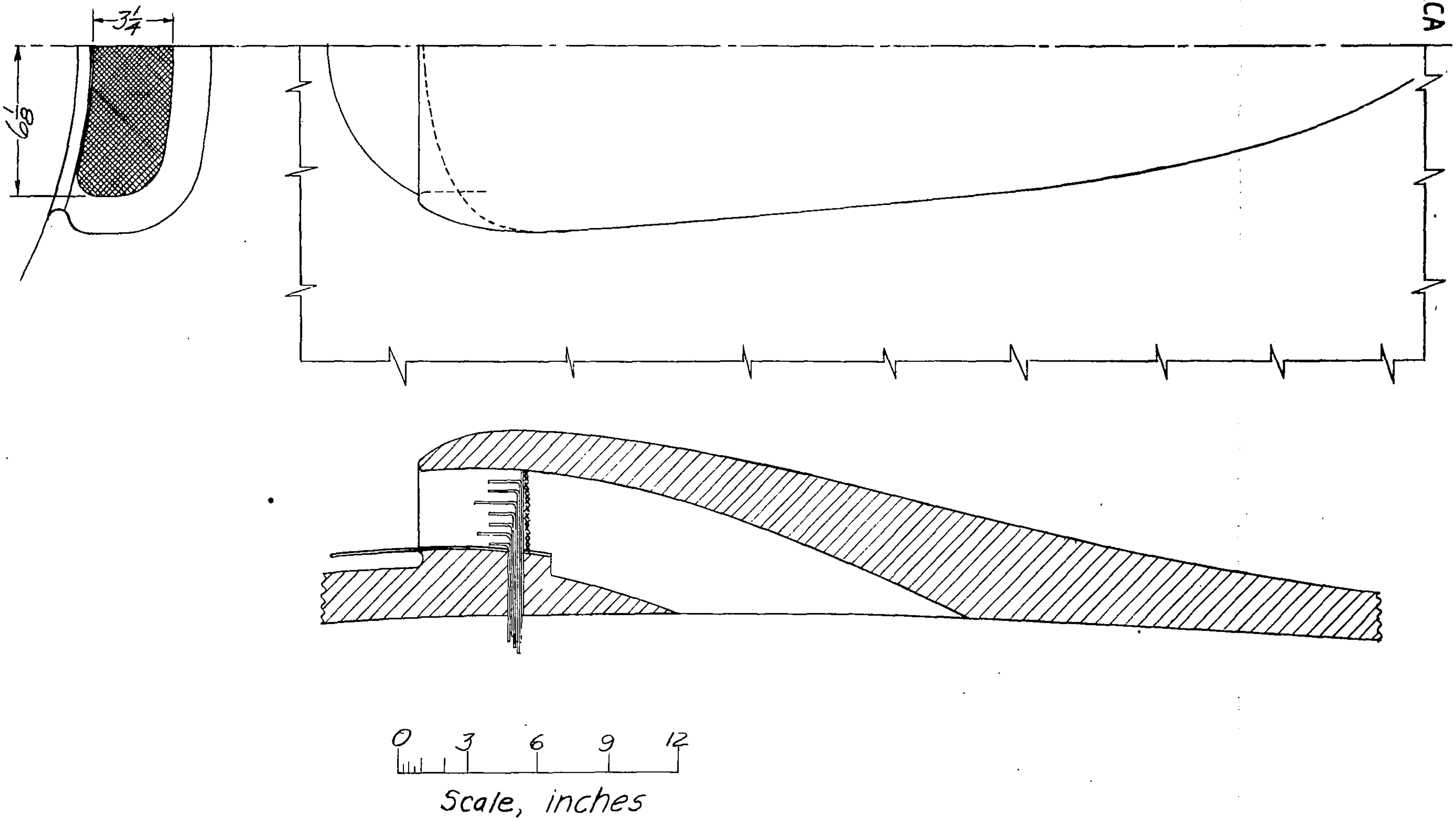

Figure 8.- Scoop B-1-c.

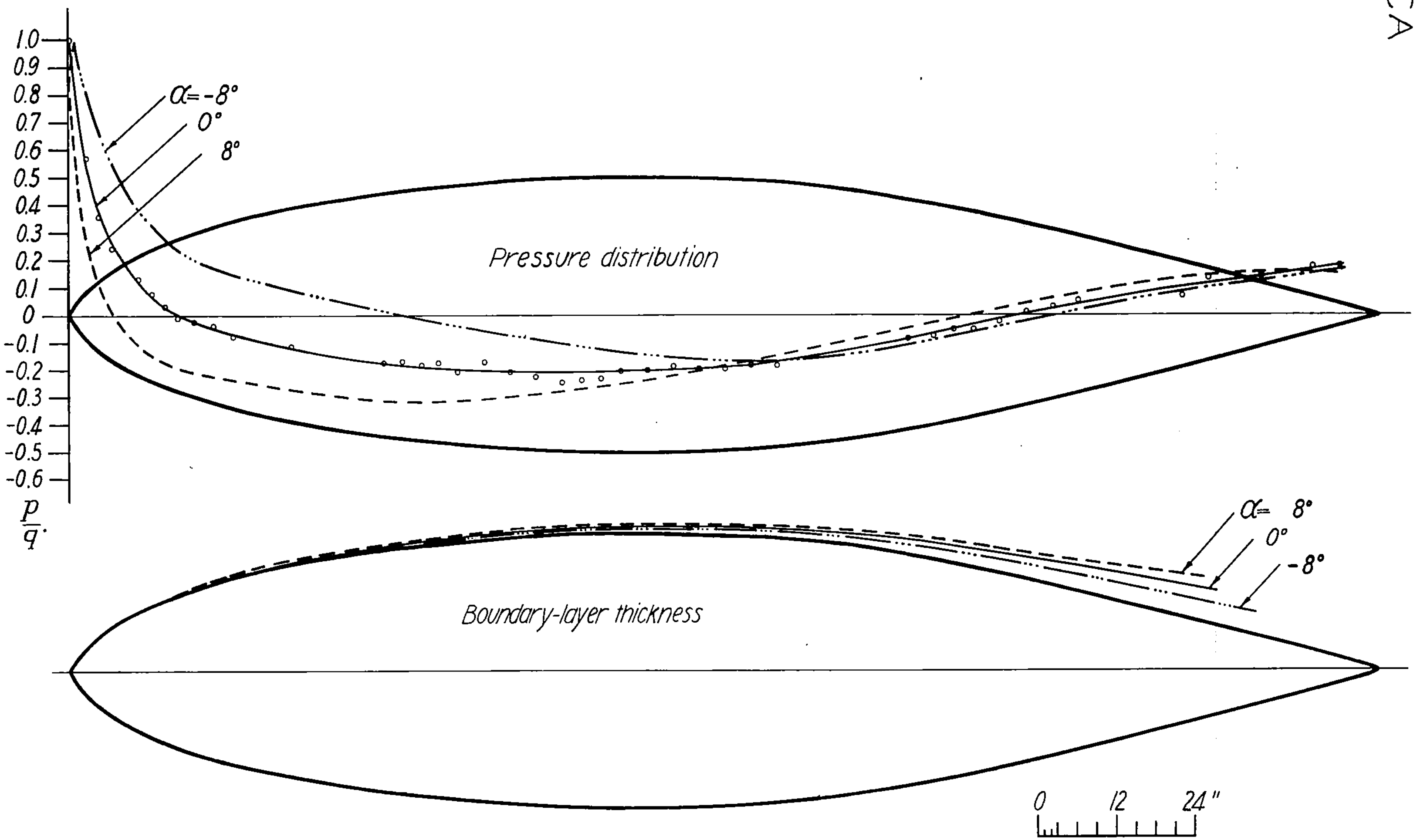

Figure 9.–Pressure distribution and boundary layer thickness on fuselage.

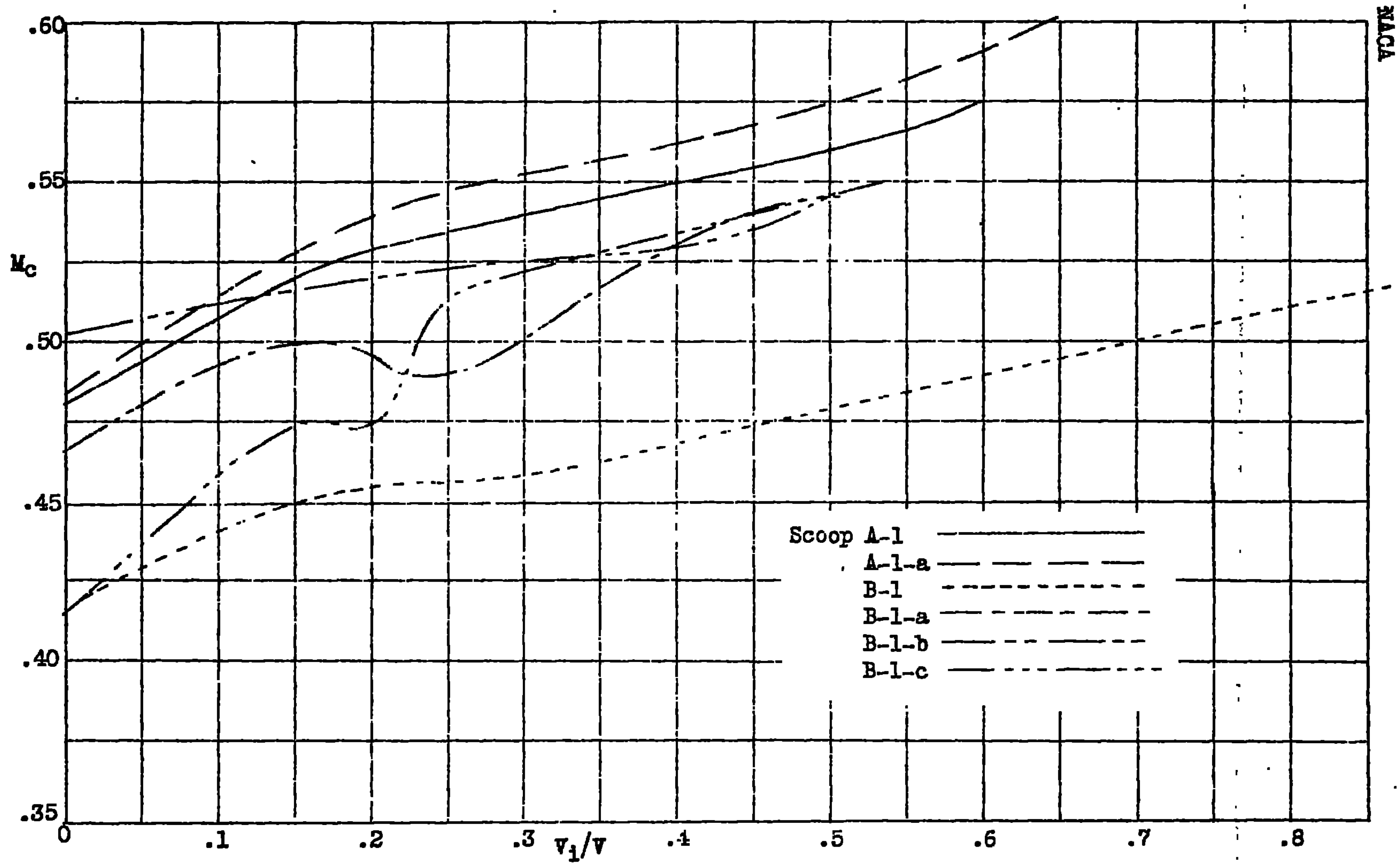

Figure 10.- Critical Mach numbers for various scoops, $\alpha = 0^o$

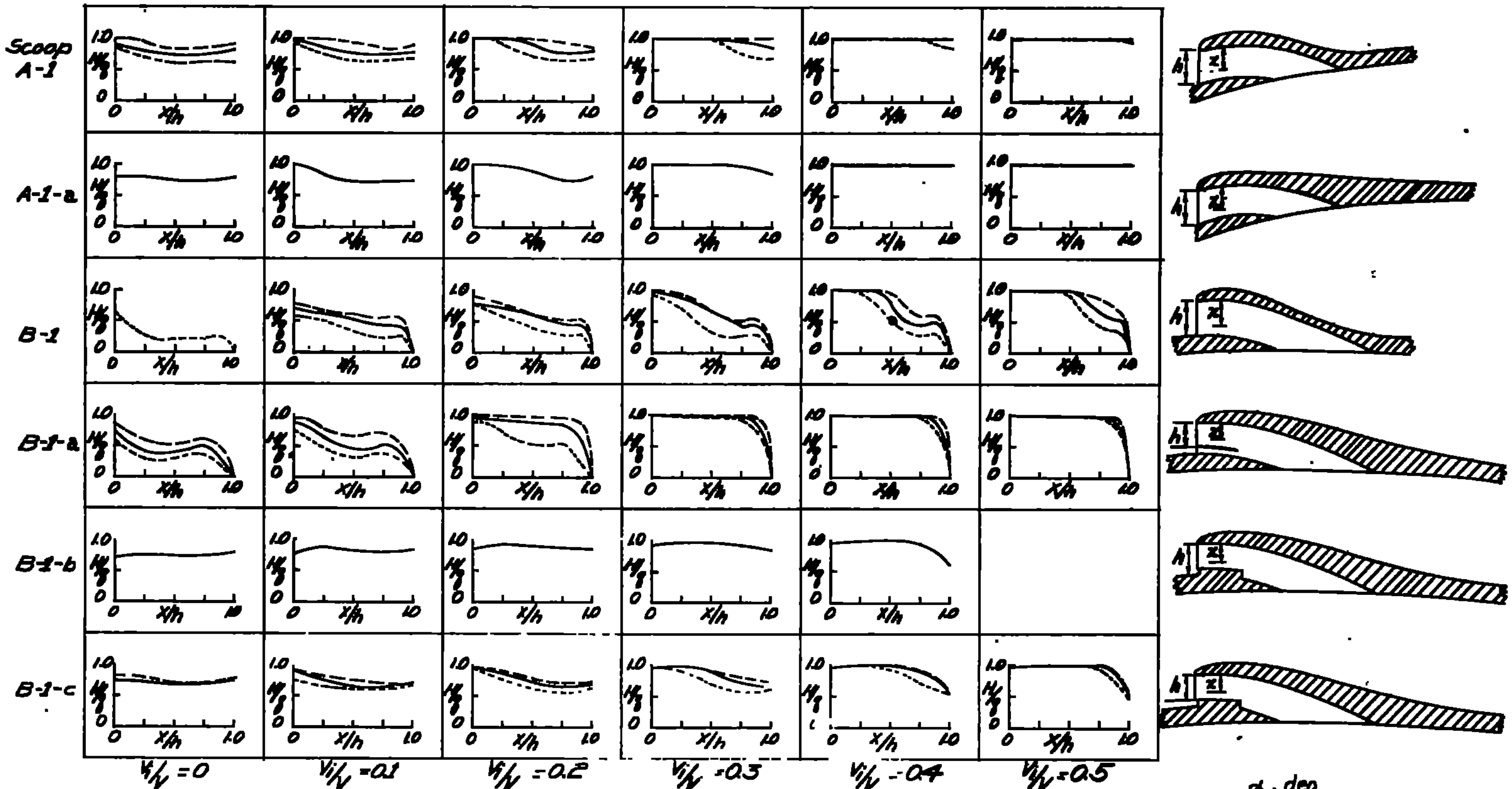

Figure 11.— Comparison of total pressures available in scoop entrances.

(Measure with 60ths scale)

α, deg
8 - - - - - -
0 ———
-8 — — —